Chapter 13

Neutrosophy and Plithogeny Applied in Medicine:Toward a Multi-Valued Logic Framework for Clinical Decision-Making and Biomedical Uncertainty

Florentin Smarandache

University of New Mexico, Gallup, USA
Email: smarand@unm.edu
Corresponding author's email: smarand@unm.edu

ABSTRACT

Medicine is a discipline defined by uncertainty. Diagnoses are rarely absolute: a symptom may simultaneously suggest multiple conditions, a treatment may be effective for one patient and harmful for another, and clinical evidence is frequently incomplete, contradictory, or indeterminate. Classical binary logic, where a proposition is either true or false, is inadequate for capturing this complexity. This paper explores how two advanced philosophical and mathematical frameworks developed by Florentin Smarandache, neutrosophy and plithogeny, can be systematically applied to medical science to address its inherent ambiguities.

Neutrosophy introduces a tripartite truth-value system (truth, indeterminacy, falsity) that transcends both classical and fuzzy logic, enabling richer representations of diagnostic uncertainty, contradictory evidence, and unknown factors. Plithogeny, as its extension, models entities characterized by multiple attributes simultaneously, accommodating the multidimensional nature of disease, patient profiles, and biomedical data. We examine these frameworks in the contexts of diagnostic reasoning, clinical decision support systems, medical ontologies, epidemiology, and multi-criteria drug evaluation. This chapter argues that neutrosophic and plithogenic tools offer transformative potential for advancing precision medicine, artificial intelligence in healthcare, and evidence-based clinical practice.

Keywords: Neutrosophy, plithogeny, neutrosophic logic, medical diagnosis, clinical uncertainty, plithogenic set, evidence-based medicine, artificial intelligence in medicine, fuzzy logic, indeterminacy

INTRODUCTION

Medical practice fundamentally operates in conditions of partial information and uncertainty [1]. A physician seldom encounters a textbook case where symptoms align perfectly with a single diagnosis; more often, multiple diagnoses must be weighed, probabilities estimated, and decisions made despite incomplete or conflicting evidence. Classical propositional logic, which assigns a truth value of either true (1) or false (0) to any statement, fails to adequately represent this reality. Even fuzzy logic, which allows for partial truth values on a continuous scale from 0 to 1. does not capture the full complexity of medical reasoning, as it does not model indeterminacy as a distinct epistemic category.

Neutrosophy, a new branch of philosophy developed by Florentin Smarandache [2], addresses this gap by introducing a three-component truth-value: T (degree of truth), I (degree of indeterminacy), and F (degree of falsity), each independently ranging within [0, 1]. This framework generalizes classical logic [3] , fuzzy logic [4] , and intuitionistic fuzzy logic [5], making it uniquely suited to represent the ambiguities inherent in medicine. A symptom can be 'somewhat indicative of disease X' (partial truth), 'inconclusive with respect to disease Y' (indeterminacy), and 'unlikely to indicate disease Z' (partial falsity) simultaneously.
Plithogeny, also introduced by Smarandache [6], represents a further generalization. Where neutrosophy focuses on truth/indeterminacy/falsity as a tripartite structure, plithogeny models entities as characterized by multiple, potentially conflicting attributes simultaneously accommodating the rich multidimensionality of biological systems, patient phenotypes, and complex medical data. Together, these frameworks constitute a powerful mathematical and philosophical toolkit for reimagining how medicine processes knowledge and makes decisions.

The rest of the Chapter is organized as follows. First, an overview of neutrosophic principles and their mathematical formalism is presented. Next, plithogeny and plithogenic set theory are introduced. This is followed by a discussion of medical applications of neutrosophy, including diagnostic reasoning and clinical decision support. Subsequently, plithogenic applications in medicine, such as multi-attribute patient classification and drug evaluation, are explored. Finally, future directions and challenges are outlined, and the paper concludes with a summary of key findings.

Neutrosophy: Foundations and Formalism

Origins and Definition

Neutrosophy (from Latin neuter- neutral, and Greek sophia -wisdom) was established by Florentin Smarandache as a branch of philosophy studying the origin, nature, and scope of neutralities and their interactions with different ideational spectra [7]. Its etymological essence captures what sets it apart from prior philosophical traditions: the systematic inclusion of the neutral.
The fundamental thesis of neutrosophy [7] states that any idea <A> is T% true, I% indeterminate, and F% false, where T, I, and F are standard or non-standard subsets included in the non-standard interval $[0^-, 1^+]$. This departure from binary logic is not merely mathematical elegance, it reflects the ontological reality that most propositions in complex disciplines such as medicine occupy intermediate or contested epistemic territory.
Between any idea <A> and its opposite <Anti-A>, neutrosophy posits a continuum of neutralities <Neut-A>. This differs fundamentally from Hegelian dialectics [8, 9], which recognizes only thesis and antithesis. Neutrosophy [10] introduces a 'pluradic pyramidal scheme' in which ideas evolve through multiple states, mixing with neutral concepts before settling into a new form. In medicine, this captures how clinical knowledge evolves not in sudden reversals but in incremental refinements punctuated by periods of uncertainty.

Neutrosophic Logic and Set Theory

Neutrosophic logic [10] generalizes fuzzy logic by allowing the truth-value of a statement to be an ordered triple (T, I, F) rather than a single scalar. This enables the representation of phenomena such as contradictory evidence, where T and F are both high; unknown factors, where I is high; and certainty, where T approaches 1 and both I and F approach 0. Each component is independent, meaning that their sum need not equal 1, a critical difference from probability theory.
A neutrosophic set N on a universal set U assign to each element $x \in U$ a triple $(T_A(x), I_A(x), F_A(x))$, where each component is a real standard or non-standard subset of $[0^-, 1^+]$. In single-valued neutrosophic sets (SVNS) [11], these components are constrained to [0, 1] with $T + I + F \leq 3$, enabling practical computational implementation. Operations such as union, intersection, and complement are defined accordingly, forming a rich algebraic structure applicable to data classification and decision-making [12-22].

Neutrosophic Probability and Statistics

Beyond logic and sets, Smarandache [23] extended neutrosophy into probability theory. Neutrosophic probability assigns to each event a triple (chance of occurrence, chance of indeterminate occurrence, chance of non-occurrence) rather than a single probability value. This is particularly relevant in medicine, where clinical trials yield probabilistic estimates that are always subject to measurement error, incomplete randomization, and population heterogeneity, all forms of indeterminacy.

Neutrosophic statistics [23], by extension, concerns itself with data sets that are imprecise, uncertain, or partially known. This includes handling missing data, contradictory laboratory results, and patient self-reports that are inconsistent over time, ubiquitous challenges in clinical research.

Plithogeny: From Neutrosophy to Multi-Attribute Frameworks

Definition and Etymology

Plithogeny (from Greek plithos, plurality/multitude, and genesis, origin/creation) is a generalization of neutrosophy introduced by Smarandache [24] in 2017. Whereas neutrosophy models propositions as having three truth-values (T, I, F), plithogeny models entities as characterized by multiple attributes simultaneously, each with their own appurtenance degree functions and contradiction (dissimilarity) degree functions.

The plithogenic set [25] extends classical set [26], fuzzy set [4], intuitionistic fuzzy set [5] , and neutrosophic sets [7] by introducing an attribute value spectrum for each defining characteristic of elements. This allows the representation of the full range of possible states an entity can occupy with respect to a given attribute, weighted by a contradiction degree function that measures how far any given value is from a designated dominant value.

Plithogenic Set Formal Structure

Formally, a plithogenic set P is defined over a universe of discourse U by: a non-empty set of attribute values $V = \{v_1, v_2, ..., v_n\}$; an attribute value appurtenance degree function $d: U \times V \rightarrow P([0,1]^s)$, where $s \in \{1, 2, 3\}$ depending on whether the set is fuzzy (s=1), intuitionistic fuzzy (s=2), or neutrosophic (s=3); and an attribute value contradiction degree function $c: V \times V \rightarrow [0, 1]$ that measures the dissimilarity between any two attribute values.

The plithogenic aggregation operators, intersection, union, and complement combine information from all attribute values using a weighted formula that incorporates the contradiction degree function. This ensures that dominant attribute values contribute more strongly to aggregated decisions, while highly dissimilar (contradictory) values receive differential weighting. The result is a mathematically rigorous framework for multi-criteria decision analysis.

Plithogenic Logic and Probability

Plithogenic logic [24,25] extends neutrosophic logic [7] by allowing the truth-value of a proposition to vary across an entire spectrum of attribute values rather than just a single triple (T, I, F). This reflects the reality that a proposition can be evaluated differently depending on context, perspective, or measurement method, all modeled as distinct attribute values. Plithogenic probability generalizes neutrosophic probability by assigning plithogenic truth-value distributions to events, capturing the full complexity of scenarios where outcomes depend on multiple interacting factors.

Applications of Neutrosophy in Medicine

Diagnostic Reasoning Under Uncertainty

Medical diagnosis [27, 28, 29] is perhaps the most natural domain for neutrosophic logic application. Consider a patient presenting with fatigue, mild fever, and joint pain. A physician must assess: is this rheumatoid arthritis, systemic lupus erythematosus, viral infection, or another condition? Classical binary assessment (disease present / disease absent) is clinically unrealistic. Fuzzy logic allows partial truth but cannot distinguish between 'partially true due to genuine partial fit' and 'partially true due to missing information', the latter being classic indeterminacy.

With neutrosophic logic, the physician can formally represent: 'Evidence for rheumatoid arthritis: T= 0.6, I= 0.25, F= 0.15' and 'Evidence for viral arthritis: T=0.5, I=0.35, F=0.15.' The separate indeterminacy component captures what is not yet known, awaiting laboratory results, imaging, or further history, and can guide targeted investigation. This richer representation supports more transparent and auditable clinical reasoning.

Clinical decision support systems (CDSS) built on neutrosophic logic have been proposed [30] and studied for conditions including cancer screening, sepsis identification, and cardiac risk stratification. In each domain, the

ability to explicitly model indeterminacy reduces premature diagnostic closure, a well-documented source of medical error, and supports appropriate escalation of uncertainty to specialists or further testing.

Medical Ontologies and Knowledge Representation

Medical ontologies such as SNOMED CT and ICD-11 represent clinical concepts in hierarchical structures. However, many clinical concepts are inherently imprecise: 'mild hypertension,' 'probable dementia,' 'borderline diabetes.' These terms resist binary categorization. Neutrosophic set theory provides a natural enrichment of medical ontologies by allowing each concept membership to be represented as (T, I, F) triples, capturing graduated degrees of category membership, diagnostic confidence, and definitional ambiguity.

Furthermore, neutrosophy's fundamental theory that every idea tends to be neutralized by opposing ideas — has epistemological value in medicine. It formalizes how clinical guidelines are always provisional: a treatment endorsed as the standard of care (T-value high) may have accumulated evidence of harm in specific populations (rising F-value) and unresolved questions for subpopulations (high I-value). Neutrosophic ontologies can dynamically represent this evolving knowledge state.

Neutrosophic Epidemiology

Epidemiological studies are foundational to evidence-based medicine but are inherently probabilistic and subject to indeterminacy. Confounding variables, incomplete follow-up, measurement error, and population heterogeneity all introduce indeterminate components into epidemiological estimates. Neutrosophic probability, by assigning (T, I, F) triples to event occurrence, provides a more complete characterization of epidemiological risk than classical probability alone.

For example, in a cohort study examining the association between a dietary factor and cardiovascular disease, the neutrosophic probability of a participant developing disease might be represented as (0.12, 0.06, 0.82), where 0.12 is the classical probability estimate, 0.06 reflects measurement indeterminacy from dietary recall bias, and 0.82 represents non-occurrence. This representation makes explicit the epistemic limitations of the study, enabling more nuanced meta-analytic synthesis.

Neutrosophic Approaches in Pharmacology

Drug development and pharmacological evaluation involve inherent uncertainty at every stage: from target identification (is this protein truly implicated in the disease mechanism?) to clinical efficacy (does the drug work in the full target population?) and safety (are observed adverse events causally linked to the drug?). Each of these questions involves not just probabilistic answers but irreducible indeterminacies.

Neutrosophic frameworks have been proposed for evaluating drug safety signals in pharmacovigilance databases, where adverse event reports are often incomplete, inconsistently coded, and subject to reporting bias. A neutrosophic safety signal for a drug-event pair, for instance, (T=0.55, I=0.30, F=0.15), explicitly conveys both the degree of evidence for a causal association and the degree of unresolved uncertainty, guiding regulatory decision-making more transparently than simple frequentist p-values.

Applications of Plithogeny in Medicine

Multi-Attribute Patient Classification

Patients are not one-dimensional entities. They are characterized simultaneously by genetic factors, comorbidities, lifestyle attributes, socioeconomic determinants, medication histories, and psychosocial profiles. Classical classification schemes such as staging systems for cancer or risk scores for cardiovascular disease, aggregate these attributes into single scalars, inevitably losing information. Plithogenic set theory preserves multi-attribute complexity by modeling each patient as an element of a plithogenic set, with appurtenance degrees defined for every relevant attribute [31, 32].

For example, in oncology, a patient with colorectal cancer might be characterized across attribute dimensions including: tumor histology (dominant value: adenocarcinoma), molecular profile (dominant value: microsatellite stable), stage (dominant value: Stage IIIB), comorbidity burden (dominant value: moderate), and treatment history (dominant value: chemotherapy-naive). Each attribute has a contradiction degree function measuring how

different a given patient's value is from the dominant, enabling nuanced risk stratification that preserves individualized information while enabling population-level pattern recognition.

Multi-Criteria Drug and Treatment Evaluation

Therapeutic decision-making routinely requires balancing multiple competing criteria: efficacy, safety, cost, patient preference, and compatibility with existing treatments. Multi-criteria decision analysis (MCDA) methods are increasingly used in health technology assessment, but classical MCDA models require precise numerical inputs and do not handle interdependence among criteria or linguistic imprecision in evaluator judgments.

Plithogenic MCDA addresses these limitations. Each treatment option is modeled as an element of a plithogenic set defined over criteria attributes. Appurtenance degrees capture how well each treatment aligns with each criterion, while contradiction degree functions model how conflicting criteria trade off against each other. Plithogenic aggregation operators synthesize this multi-attribute information into a composite recommendation that preserves uncertainty information rather than collapsing it prematurely. This approach has been applied to antimicrobial treatment selection and immunotherapy sequencing decisions.

Plithogenic Medical Imaging and AI

Medical imaging including radiography, computed tomography, magnetic resonance imaging, and pathological image analysis generates multi-attribute data. A lesion on a scan is characterized simultaneously by its size, shape, intensity distribution, border characteristics, enhancement pattern, and location. Machine learning models trained on such data typically output a single probability score; plithogenic models can instead output a multi-attribute assessment that maps these dimensions independently, providing richer information for radiologists and clinicians.

Deep learning architectures augmented with plithogenic set operations can represent the uncertainty of each attribute assessment independently, enabling uncertainty quantification in AI-assisted diagnosis that is both mathematically rigorous and clinically interpretable. Preliminary studies have demonstrated this approach for pulmonary nodule characterization and diabetic retinopathy grading, showing that plithogenic models achieve comparable or superior performance to classical deep learning while providing richer uncertainty characterization.

Epidemiological Modeling with Plithogenic Probability

Infectious disease epidemiology routinely grapples with multi-attribute uncertainty. During the emergence of a novel pathogen, epidemiologists must simultaneously assess transmissibility (by multiple routes), severity (across demographic subgroups), immune evasion (relative to existing immunity), and environmental persistence — each with its own uncertainty profile. Plithogenic probability provides a natural framework for this multi-dimensional uncertainty quantification.

In pandemic preparedness modeling, plithogenic distributions over key epidemiological parameters can capture correlated uncertainties (e.g., higher transmissibility may covary with lower immune evasion in some evolutionary scenarios) while maintaining the independence of distinct epistemic components. This enables more realistic sensitivity analyses and scenario planning, informing public health interventions with clearer representations of what is known, what is unknown, and what is contested.

Future Directions and Challenges

Integration with Clinical Data Systems

The practical implementation of neutrosophic and plithogenic frameworks in clinical medicine requires integration with electronic health record (EHR) systems, clinical decision support tools, and medical AI platforms. Current EHR systems are designed around structured, predominantly binary or categorical data. Adapting these systems to accommodate neutrosophic (T, I, F) triples or plithogenic multi-attribute representations will require new data standards, interface designs, and clinician training.

Promising avenues include hybrid systems where neutrosophic/plithogenic representations exist in a dedicated reasoning layer that communicates with underlying EHR data in standard formats, translating uncertainty

information into actionable clinical alerts or summaries. Standards bodies such as HL7 FHIR may be extended to include uncertainty quantification extensions compatible with neutrosophic representations.

Educational and Cultural Challenges

The adoption of neutrosophic and plithogenic thinking in medicine also requires a cultural shift. Medical education has historically emphasized pattern recognition and decisive action, sometimes at the expense of explicit uncertainty communication. Physicians trained in classical logic may find the tripartite truth-value system counterintuitive. However, increasing emphasis on diagnostic humility, shared decision-making, and evidence-based uncertainty communication in modern medical education creates a favorable context for these frameworks.

Validation and Empirical Research

A critical need for the field is rigorous empirical validation of neutrosophic and plithogenic medical applications. While theoretical justifications are strong, clinical validation studies are required to demonstrate that CDSS built on these frameworks improve patient outcomes, reduce diagnostic error, or enhance clinician confidence relative to classical or fuzzy logic alternatives. Such studies should employ prospective cohort designs with clinically meaningful endpoints and include assessment of the interpretability and usability of uncertainty outputs by clinicians.

Conclusion

Medicine is, at its core, a discipline of managed uncertainty. From the first clinical encounter to the final therapeutic decision, physicians navigate a landscape of partial information, conflicting evidence, and irreducible unknowns. Classical and even fuzzy logical frameworks, while useful, are insufficient to capture the full depth of this epistemic complexity.

Neutrosophy, through its tripartite (T, I, F) truth-value structure, provides a philosophically grounded and mathematically rigorous means of representing diagnostic uncertainty, contradictory clinical evidence, and genuine indeterminacy. Plithogeny, as its multi-attribute extension, opens further vistas for modeling the multidimensional nature of patients, diseases, and therapeutic contexts. Together, they constitute a comprehensive and transformative framework for rethinking medical knowledge representation, clinical decision-making, and biomedical AI.

The application of these frameworks to medical diagnosis, pharmacology, epidemiology, clinical imaging, and multi-criteria treatment evaluation demonstrates both conceptual richness and practical promise. As precision medicine increasingly demands individualized, data-driven, uncertainty-aware clinical reasoning, neutrosophic and plithogenic tools stand ready to provide the logical and mathematical infrastructure this evolution requires.

We anticipate that future interdisciplinary collaboration among philosophers, mathematicians, biomedical informaticists, and clinicians will catalyze the translation of these powerful frameworks from theoretical innovation to clinical practice, ultimately serving patients who deserve decisions made with the fullest and most honest representation of what medicine knows, what it suspects, and what it does not yet know.

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